

UNDERSTANDING WOOD DISCOLORATION HELPS MAXIMIZE WOOD PROFITS

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Wood discolorations are an old problem and they can be defined as abnormal color patterns. Wood discolorations mainly cause a cosmetic, surface damage but because the surface is the visible part of wood such discolorations can have an immediate impact on a customer. Exceptionally, discolorations can also accompany significant reductions of structural- and physical wood properties. Discolorations can develop in both hardwoods and softwoods but light-colored woods (whitewoods) of both types are particularly prone to this problem. In the Pacific Northwest of North America we have several light-colored softwoods, for instance western hemlock, true firs, yellow cedar, all with excellent structural properties and exceptional beauty. They are widely used for joinery, mouldings and other fine millwork in Europe and other overseas markets. In service whitewoods are often coated with a clear finishes to enhance their natural appearance. At present customers are willing to pay a high price for clear, stain-free material; conversely discolorations often result in downgrade and in loss in revenues.

With the move towards added-value products and with higher quality product specifications discolorations have become an important, economic problem. Therefore color defects are less tolerable. Other factors may influence the importance of wood discolorations, for instance the increasing use of second-growth timbers which contain more sapwood and which can suffer from improper handling practices of sawn lumber.

The protection of lumber and timbers against discoloration requires both an understanding of the normal coloration patterns in wood and the cause and factors which produce abnormal colorations.

CLASSIFICATION OF WOOD DISCOLORATIONS

Wood discolorations can be divided in microbial (biological) and non-microbial, based on their causes.

Microbial (biological)

- * Sapstaining fungi
- * Mould fungi
- * Incipient decay

Non-microbial (chemical)

- * Photochemical
- * Biochemical
- * Chemical
- * Brownstain

MICROBIAL DISCOLORATIONS

Sapstain: The most obvious form of discolorations, called sapstain or bluestain, is caused by the presence of pigmented fungi infecting wood. These fungi colonize mainly the sapwood and cause a bluish, greyish or black coloration to the wood. Although appearing to be stained the wood itself is not stained but the discoloration results from an accumulation of pigmented (brown, black) fungi as they grow within the wood cells.

Moulds: Fungi, which cause discoloration adherent at the wood surface only. Moulds have vegetative cells (hyphae) which are colorless and thus differ from the pigmented sapstaining fungi. Under suitable conditions they produce masses of colored

spores at the wood surface. Because the spores can be readily brushed or planed off, restoring the natural wood appearance, discolorations caused by moulds are of minor importance where the wood is to be remanufactured. However, their visual impact on the wood surface may be economically important at the point of sale of that wood product.

Incipient decay: Wood decaying fungi can also produce color changes in wood during incipient decay. These color changes are often subtle ranging from shades of red, brown, purple, grey or white. They may sometimes be distinguished from sapstaining by the presence of dark zone lines in the wood separating the incipient decay from normal wood.

Growth Requirements For Sapstain And Mould Fungi

Fungi causing wood discolorations have essential growth requirements. As for all living organisms they need oxygen, nutrients (food), water and a favourable temperature. These four requirements are linked and fungal growth won't commence, or it becomes arrested, when one of the four factors is missing.

Oxygen: Freshly felled trees and freshly sawn lumber generally contain sufficient oxygen to allow for fungal growth. Generally fungi are unable to grow in water-saturated wood with a moisture content greater than 120%. Under those conditions there is insufficient oxygen to permit fungal growth. Therefore one strategy to reduce the risk of sapstaining in freshly felled logs is to keep the logs in water-saturated conditions, either through ponding, or sprinkling. Done properly this procedure can keep logs stain-free for years.

Nutrients: Freshly felled logs and freshly sawn lumber contain abundant, readily available, nutrients (sugars, proteins, lipids) in their sapwood which support growth of sapstain and mould fungi. These nutrients are present to a much lesser degree in the heartwood which therefore present a much less hospitable environment for growth. Nutrients are still present in kiln-dried lumber and discolorations can occur upon rewetting. Also kiln-drying can cause redistribution of nutrients resulting in an accumulation of nutrients at the wood surface. This can increase the risk of mould growth on lumber under favourable conditions.

Water: Sapstaining fungi need free water to colonize and to grow in wood. By definition wood must be above fiber saturation point to allow active fungal growth. Nevertheless it is important to note that fungi can survive in wood well below fiber saturation point, at moisture content below 20%, for many months and they can resume sapstaining activity upon rewetting of the wood. As already mentioned water-saturated wood is protected against discolorations.

Temperature: The optimal temperature for the growth of most sapstaining fungi and moulds in the Pacific Northwest of North America ranges between 15-30°C. Nevertheless these fungi can grow over a wide temperature range (0-35°C) and they can survive very low temperatures whereas high temperatures (above 45°C) are usually lethal. Generally, fungi are killed during regular kiln-drying schedules thereby protecting wood from internal staining.

Dissemination And Growth Of Wood-Staining Fungi

Germinating spores often introduce discolorations to freshly felled logs or freshly sawn lumber. Spores can be airborne, spread through rain splash or they can be vectored through insects, for instance bark beetles or ambrosia beetles. The exact mode of infection (airborne versus vectored) is rarely understood for a particular wood staining fungus. No doubt there is higher risk of infection through spore dissemination in sawmills, lumber yards and sorting yards. It is worth mentioning that fungal

staining can also originate when clear wood comes in physical contact with pre-infected wood, for instance when using discolored stickers or when clean wood comes in contact with contaminated machinery.

Under favourable conditions fungal spores can germinate within hours after landing on wood. The fungus can then quickly penetrate the wood. Some fungi can grow up to 5 mm longitudinally and 1 mm radially within wood over a 24 hour period. These growth rates underscore the importance of starting wood protection soon after logging or the sawing of lumber.

Effect On Wood Properties

While discolored wood is mainly a cosmetic problem, the wood properties can also be affected. For instance toughness (impact strength) may be significantly reduced following infection by staining fungi. Toughness is very critical in applications, such as wooden handles for tools and ladders, which are subject to shock loading.

Sapstain fungi and moulds also increase the permeability of wood by degrading pit membranes which connect adjacent wood cells by physically boring holes between adjacent wood cells. As a result discolored wood dries more rapidly. This can cause differences in moisture content within and between boards when kiln-drying. In addition, infected wood will also absorb water more quickly thereby increasing the risk of checking and decay in service. Wood infected by sapstain and mould fungi will also absorb solutions more rapidly than clear wood which can cause problems in both protecting and finishing wood.

Wood Protection

Wood protection should start at the time of logging. It becomes particularly important under warm and humid conditions when the risk of infection by micro-organisms (bacteria and fungi) is highest. Discolorations initiated in the living tree can not be restored. Ponding or sprinkling of freshly felled logs are well known methods to reduce sapstain development during log storage (between felling of logs and processing into kiln-dried lumber). When lumber is produced antisapstain chemicals are best applied within 24 hours otherwise fungi can penetrate the wood beyond the reach of the chemicals. Proper stacking and covering of treated, green lumber during storage and shipment is also mandatory to avoid sapstain problems. Kiln-dried wood is protected against sapstain unless it becomes rewetted either in transit or storage.

NON-MICROBIAL DISCOLORATIONS

Other discolorations of concern, called "non-microbial" discolorations, differ from fungal stain in that no microbial activity is necessary for coloration development. Non-microbial discolorations result from chemical changes in the wood, producing colored wood extractives which are deposited in the lumen of wood cells. Most discolorations develop when green wood (logs or lumber) is exposed to air. In contrast to sapstain non-microbial discoloration can occur in both sapwood and heartwood, where they can develop at the surface or deep within the wood. Non-microbial discolorations are not well understood for most wood species. To determine the causes of non-microbial discolorations one has to understand factors such as wood extractive composition, temperature, humidity, light and storage conditions.

Photochemical: Light (visible and ultraviolet) also changes the color of the wood surface, the intensity depending on the wood species. Some woods become bleached or grey, others yellow or brown. Light induced-discolorations are influenced by the wood composition and by the wood extractive composition. Color changes are

further influenced by factors such as temperature, water and atmosphere. The natural color of affected wood can be restored by planing. Certain chemicals (UV absorbers such as chromium compounds) can protect wood from color changes by light. Softwoods such as spruce and pine and hardwoods such as oak and maple are highly prone to color changes. This problem is of particular concern for high grade lumber used for panelling and other finishes.

Biochemical: Enzymes present in wood can onset oxidation of extractives to produce discolorations following felling of trees or sawing of lumber. These discolorations are analogous to browning reactions in freshly cut fruit, for instance in apples.

Discolorations of red alder are an excellent example of a biochemical discoloration. Intense red/brown discolorations or mottling can develop rapidly in unseasoned red alder lumber during air-seasoning or kiln-drying. Rapid inactivation of enzymes present in fresh red alder can prevent the discolorations. For instance presteaming at 100°C of fresh-sawn or air-seasoned red alder before kiln-drying can produce better color uniformity.

Chemical: Intense discolorations can develop in green wood with a high tannin content upon contact with iron. The discoloration is produced at the wood surface and occur wherever contact with iron was made. Oak wood is well known to produce grey or black iron tannin stains. Analogous western hemlock and western red cedar can also develop intense grey or black iron tannin stains. Iron caused discolorations may stem from sawmill machinery, metal straps when packaging lumber, or from metal fittings. Iron tannin stain may be readily controlled by avoiding immediate contact of iron with the wood. For instance the use of non-metal straps when packaging lumber or providing a space between metal straps and the wood surface protects wood from this type of stain. Iron tannin stain can usually be removed either through planing or chemically with oxalic acid. Kiln-dried wood is protected from chemical discolorations providing rewetting is eliminated.

Brownstain: Brown discolorations can develop in western softwoods, for instance in western hemlock and true fir (hem-fir), Douglas-fir and in ponderosa pine, following the sawing or kiln-drying of lumber. Discoloration can occur in both heartwood and sapwood and it is frequently concentrated at the board ends or at the heartwood-sapwood interface. Brownstains can be limited to the wood surface or subsurface or they may deeply penetrate the wood.

The causes of brownstains are very poorly understood. It is known that they are caused by water-soluble wood extractives which oxidize and polymerize to form a brown coloration as they migrate to the wood surface. Generally information is very sparse regarding brownstains. Most studies have attempted to control brownstains chemically or through kiln-drying. Methods are still unavailable to control brownstain in practice.

Forintek Canada Corp. has started a research program to understand the cause(s) of hemlock brownstain, the discoloration affecting both western hemlock and true firs. We have observed four different types of discolorations; brownstain, kiln-burn, zebra stain and grey stain. The most common brownstain type can develop in hem-fir logs or in sawn lumber; kiln-burn occurs in kiln-dried true fir; zebra stain occurs in kiln-dried western hemlock and grey stain can disfigure manufactured western hemlock.

Our present research focuses on the brownstain type. We have noticed that the susceptibility to brownstain is variable and only some hem-fir is prone to brownstain. A number of factors are thought to influence the production of hemlock brownstain, for instance growth sites, wood resource, felling season, log age, log and lumber

storage, time of the season and microbial involvement.

One current project is investigating the role of fungi, the effect of storage time and storage conditions in the development of brownstain. Another Forintek project will study the effect of kiln-drying adjustments which can reduce the severity of the problem, for instance by using gentle drying regimes and by reducing the amount of oxygen in the kiln. Information from these projects may help to understand some of the causal factors involved in the production of brownstain and may develop methods for its control.

CONCLUSIONS

Wood discolorations can affect the natural appearance of many wood species causing important, economic problems to the wood industry. Microbial (biological) discolorations have been widely studied for about 100 years and they are well understood. As a result discolorations caused by sapstain and mould fungi can be industrially controlled. Conversely non-microbial discolorations have received much less attention and current knowledge regarding their causes is limited. However, with the move towards value-added wood products and the use of light-colored woods, non-microbial are of increasing, economic importance. More basic research is needed to understand the factors causing non-microbial discolorations before recommendations or preventive treatments can be devised to maintain the natural color of wood.